

Gas Dynamics and Inflow in gas-rich Galaxy Mergers

Thorsten Naab & Andreas Burkert

*Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg,
Germany*

Abstract. We performed N-body/SPH simulations of merging gas-rich disk galaxies with mass ratios of 1:1 and 3:1. A stellar disk and bulge component and a dark halo was realized with collisionless particles, the gas was represented by SPH particles. Since we did not include star formation we focused on the gas dynamics and its influence on the structure of merger remnants. We find that equal-mass mergers are in general more effective in driving gas to the center. Around 50% of the gas resides in the central regions after the merger is complete. The gas in unequal-mass mergers keeps a large amount of its initial angular momentum and settles in a large scale disk while only 20% -30% of the gas is driven to the center. This general result is almost independent of the merger geometry. The gas in the outer regions accumulates in dense knots within tidal tails which could lead to the formation of open clusters or dwarf satellites. Later on, the gas knots loose angular momentum by dynamical friction and successively sink to the center of the remnant thereby increasing the total gas content of the disk. Due to the influence of the gas the simulated merger remnant becomes more oblate than its pure stellar counterpart. The shape of the stellar LOSVD changes and the third-order Gauss-Hermite coefficient h_3 is in good agreement with observations.

1. The model

The disk-galaxies are constructed in dynamical equilibrium (Hernquist 1993) and consist of an exponential stellar disk, a bulge with a Hernquist profile and a pseudoisothermal dark halo. The smaller galaxy has 1/3 of the mass and 1/3 of the particles of the massive one. The scale length is reduced by $\sqrt{1/3}$. In total we used 88888 particles for the collisionless component and 26666 gas particles simulated with SPH and an isothermal equation of state. Both galaxies approach each other on parabolic orbits with slightly inclined disks relative to the orbital plane. All simulations were performed on a Sun ULTRA 60 workstation.

2. Results

Recent simulations have shown that pure stellar 3:1 mergers of disk-galaxies lead to fast rotating (Barnes, 1998) and isotropic, disky galaxies whereas 1:1 mergers result in anisotropic, boxy ellipticals (Naab, Burkert & Hernquist 1999). We tested this hypothesis with a model that also follows the evolution of a massive

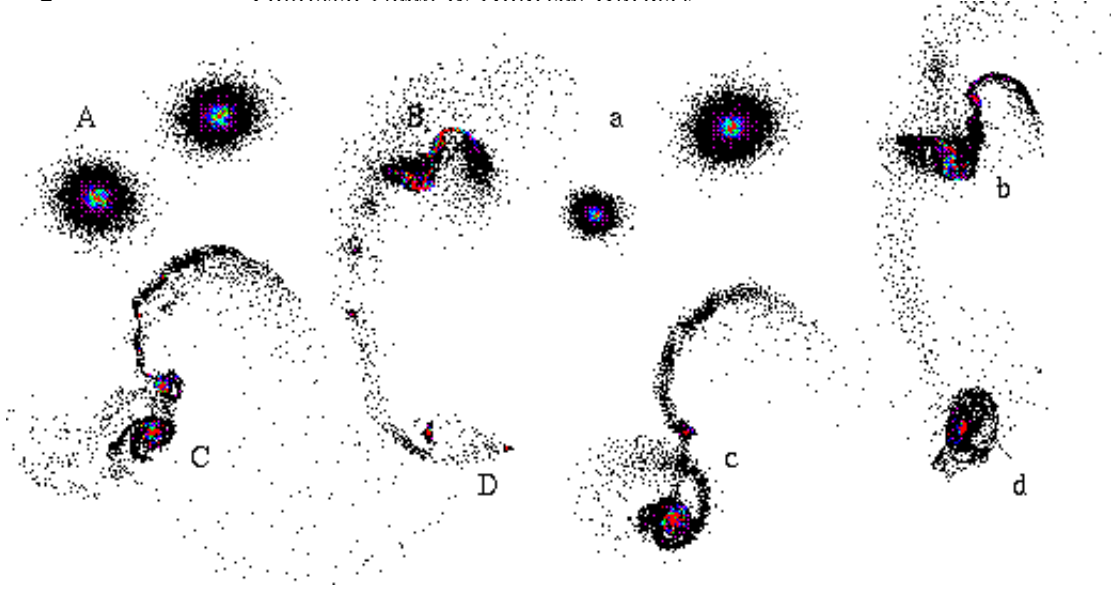


Figure 1. Snapshots of the distribution of gas particles at different time steps for the 1:1 (A,B,C,D) and 3:1 (a,b,c,d) merger simulation. At the end, for the 1:1 mergers the gas is centrally concentrated (D) whereas for the 3:1 merger the gas forms a central disk (d)

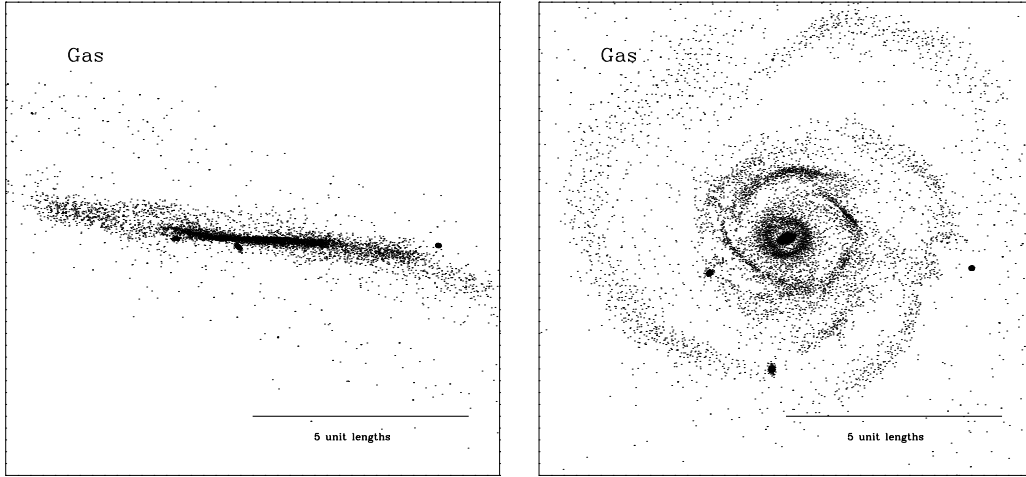


Figure 2. The distribution of the gas particles at the end of the simulation. In the edge on view (*left*) the tilt of the gas disk is clearly visible. The face-on view is shown on the right.

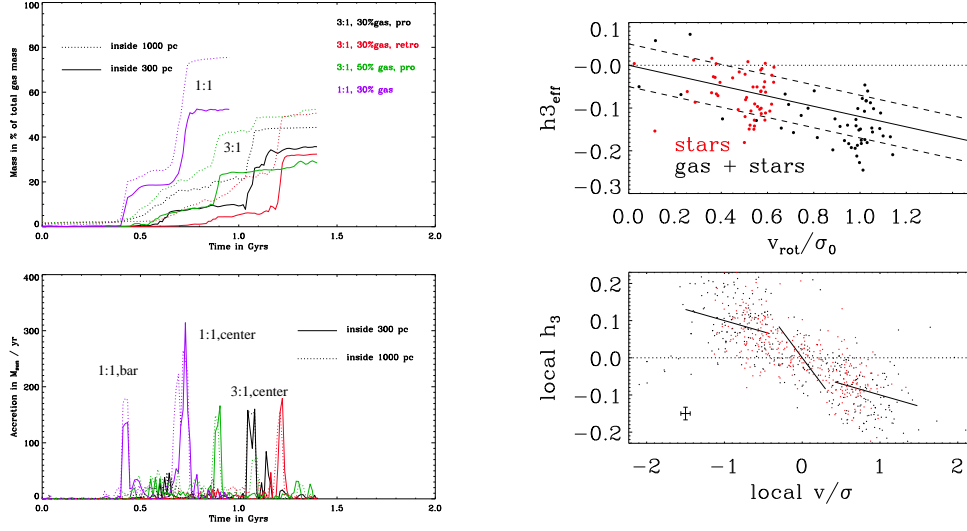


Figure 3. *Right:* Global h_{3eff} and local value of h_3 along the line of sight with and without gas particles vs. rotational support v/σ for one 3:1 merger. Data from Bender et al. (1994) are indicated by straight lines. *Left:* Upper diagram: Mass inside 300pc and 1kpc vs. time for 4 simulations. Lower diagram: Accretion rate during the bar formation and the merger of the central parts of the galaxy onto the inner 300pc and 1kpc.

gas component (see Figure 1). During the mergers a large amount of gas falls to the central region of the remnants (inside 300pc). Part of the gas is driven to the center by the formation of a tidally induced bar during the first interaction of the two disks. The accretion rate in all cases peaks when the two galaxy centers merge (Figure 3). There the gas could experience a central starburst or fuel a central black hole. Equal-mass mergers are in general more effective in driving gas to the center (Barnes & Hernquist 1996; Mihos & Hernquist 1996).

The accretion history for one selected example of a 1:1 merger is shown in Figure 3. It can be divided in two major accretion events. First the gas flows to the center along a tidally induced bar and then the two galaxy centers merge. In the end 50% of the gas is funneled into the central 300pc of the remnant. The centrifugal support of the gas in 3:1 mergers seems to be much stronger and prevents the gas from clumping at the center. Instead the gas in unequal-mass mergers settles in a large scale disk (Figure 2) and only around 30% of the gas is driven to the center, almost independent of the merger geometry (Figure 3). The gas in the outer regions accumulates in dense knots within tidal tails (see Figure 1: c and C) which could lead to the formation of open clusters or dwarf satellites. Later on, the gas knots loose angular momentum by dynamical friction and successively sink to the center of the remnant thereby increasing the gas content of the disk. As in the equal-mass case the main accretion event is the merger of the two galaxy centers.

The resulting stellar remnant has an oblate shape with disk-like isophotes and kinematical properties in good agreement with observations of faint ellipticals. In addition, we investigate the LOSVD of one unequal-mass gas-rich merger remnant. Simulations of pure collisionless unequal-mass mergers indicate a positive value of h_3 , in contrast to observations (Naab & Burkert, 2001). In gas-rich mergers the sign of h_3 changes due to the influence of the gas disk and is in good agreement with observations of massive elliptical galaxies (Bender, Saglia & Gerhard 1994). A comparison between simulated data and observations is shown in Figure 3. The stellar particles alone and together with the gas particles give the right correlation. Therefore the presence of gas and the late formation of central disks might have played an important role during the formation of elliptical galaxies.

Simulations like this can help to understand the evolution of major starbursts, AGNs and central power-law or disk-like structures that are observed in fast rotating disk ellipticals (Faber et al. 1997). We have to note that the influence of gas on the global structure of elliptical galaxies is not well understood since this influence is sensitive to some certain details about star formation which is not included in the simulations we presented here. Future investigations with better resolution (in combination with GRAPE5) and carefully implemented recipes for starformation will help to understand the role of gas dynamics and starformation in the formation history of elliptical galaxies.

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